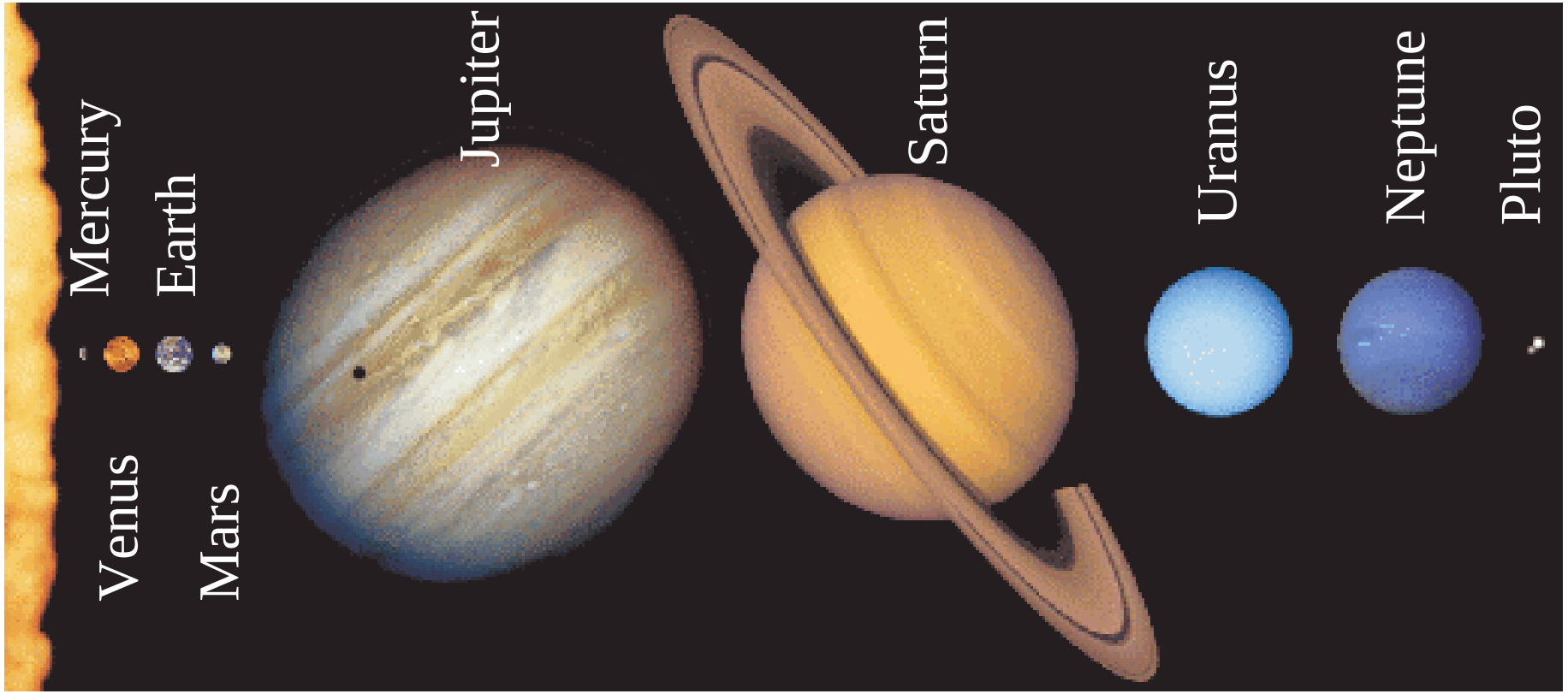
- Homework #2 was due today at 11:50am! It's too late now.
- Planetarium observing is over.
- Solar observing is over.
- Nighttime observing starts next week.

Outline

- Switch Gears– Solar System Introduction
- The Planets, the Asteroid belt, the Kupier objects, and the Oort cloud objects.

Question of Scale

- Images of all planets (from space missions), with the correct scaling.



http://www.jpl.nasa.gov/galileo/sepo/education/nav/ss2.gif

Planets Dance

http://janus.astro.umd.edu/javadir/orbits/ssv.html

Facts of the Solar System

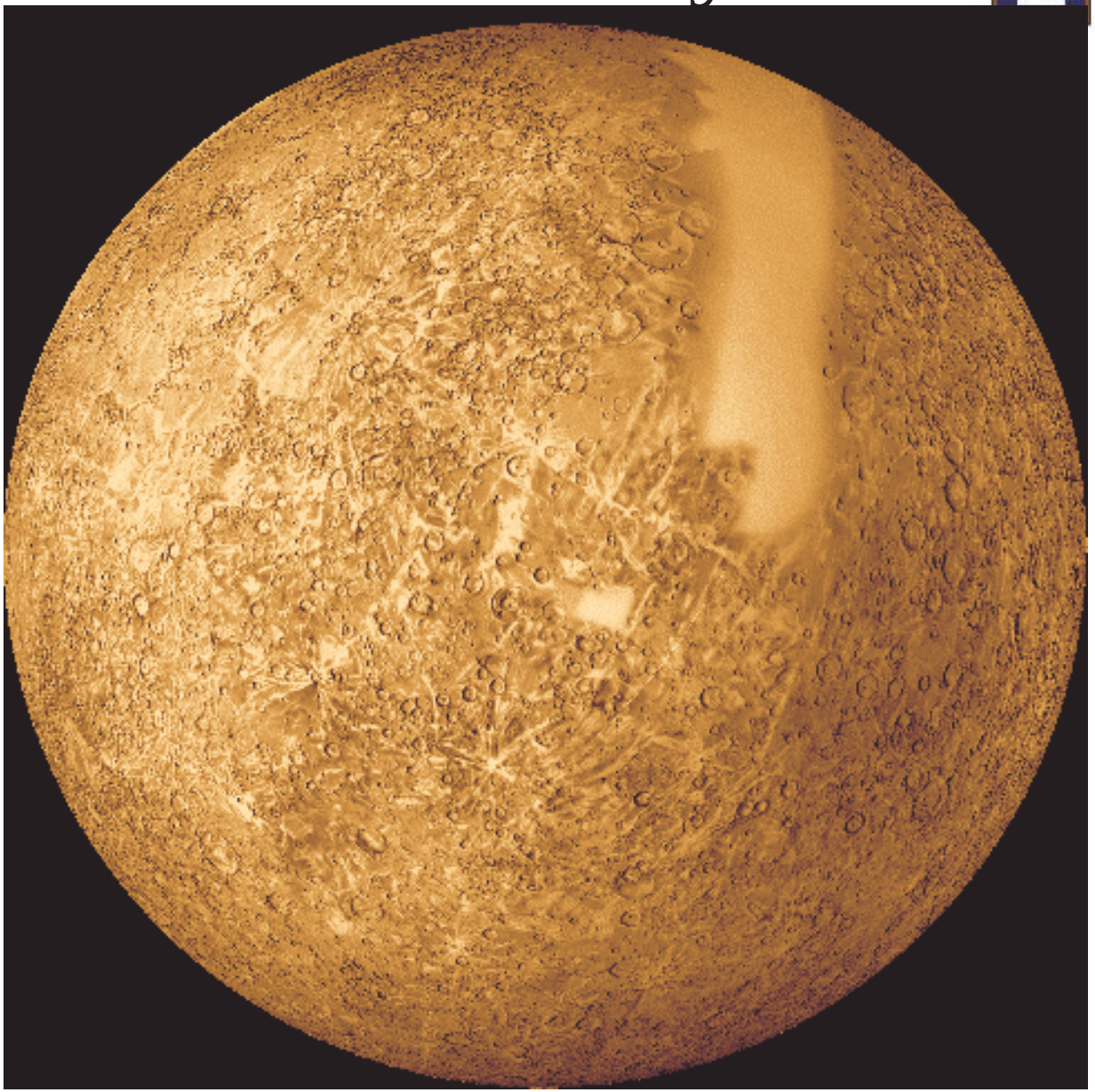
- Mass of solar system: yes, mostly in the sun, but outer planets more massive than inner
- Orbital motions in solar system are counter clockwise in a flattened system (disk)
- Orbits are actually close to circles, except Mercury and Pluto
- Chemical analysis of meteorites shows condensation sequence– variation of composition with distance from Sun

What's this Picture of?

http://www.whfreeman.com/discovering/DTU/EXMOD36/F3609.HTM

Inner Planets: Mercury

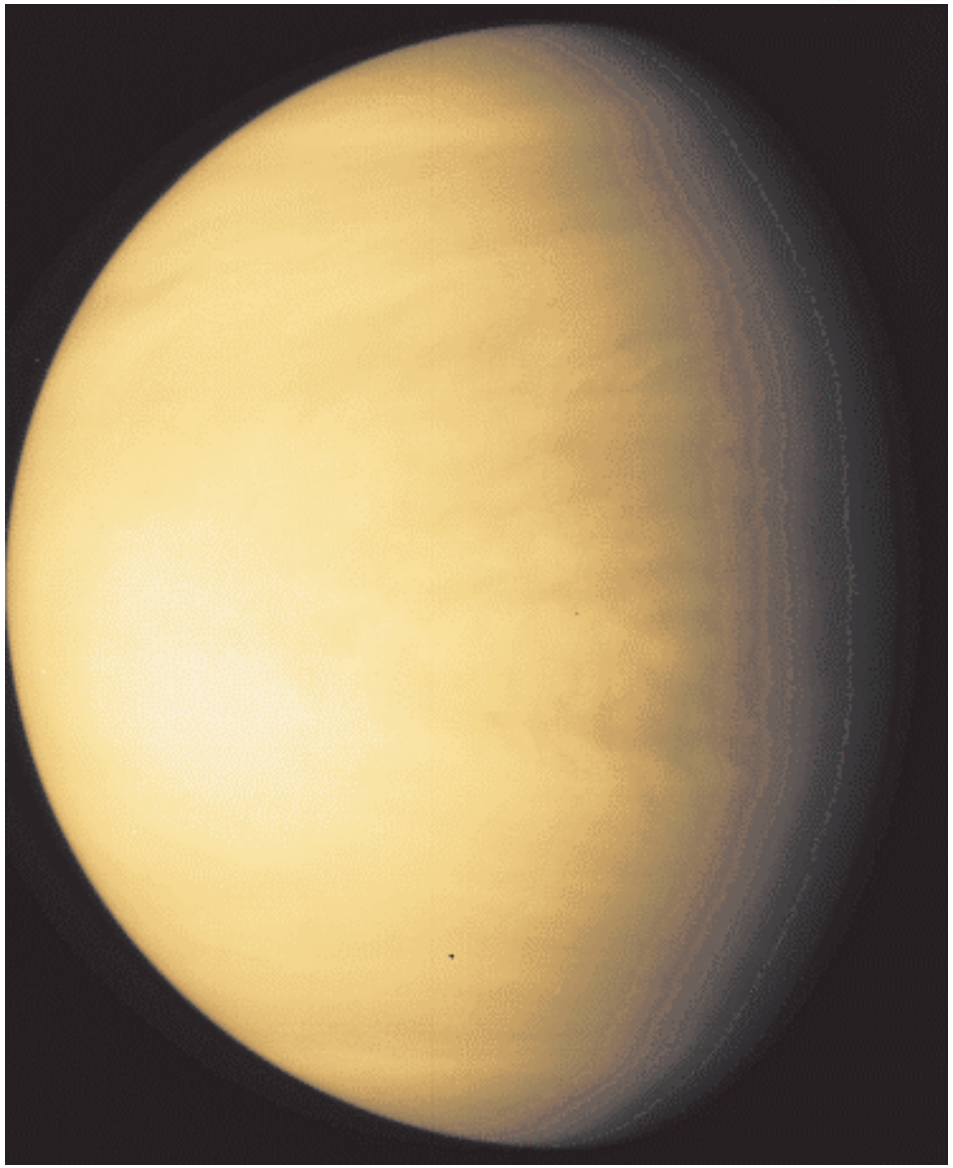
- Closest planet to Sun- 0.38 AU.
- Similar to Moon– smaller than Ganymede or Titan.
- Reaches its greatest angular separation from the Sun on Sept. 27th (rises 1 hr 20 mins before the Sun) easily visible at pre-dawn sky. Look for it below Jupiter.



http://www.jb.man.ac.uk/public/nightsky.html

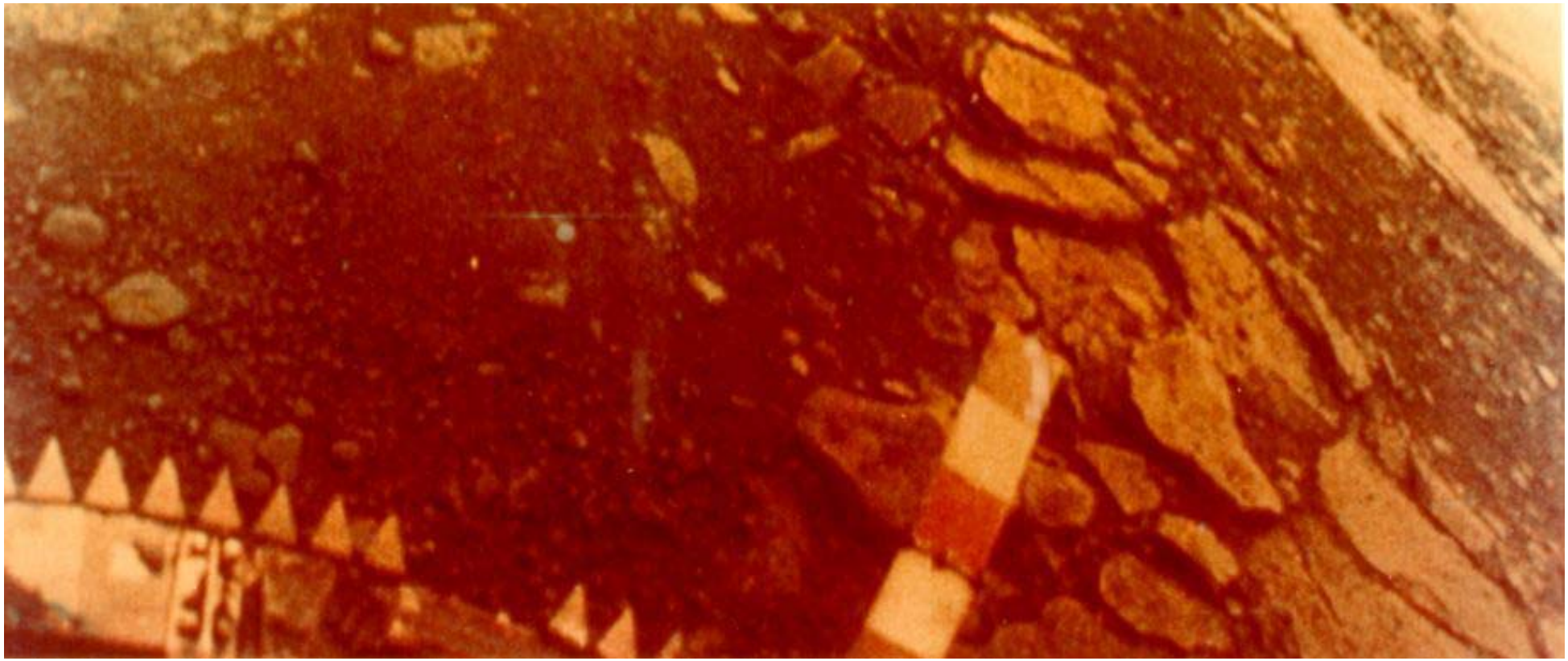
Inner Planets: Venus

- 0.72 AU from Sun
- Similar in size and mass to Earth.
- Thick clouds make it the hottest planet.
- Often called the morning star or the evening star. 3rd brightest object in the sky.



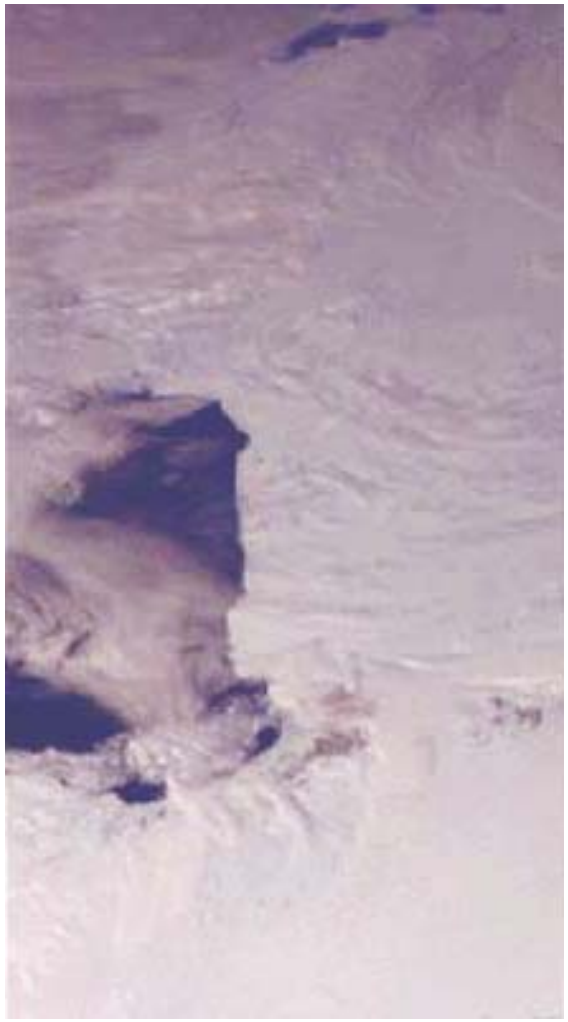
http://antwrp.gsfc.nasa.gov/apod/ap960923.html

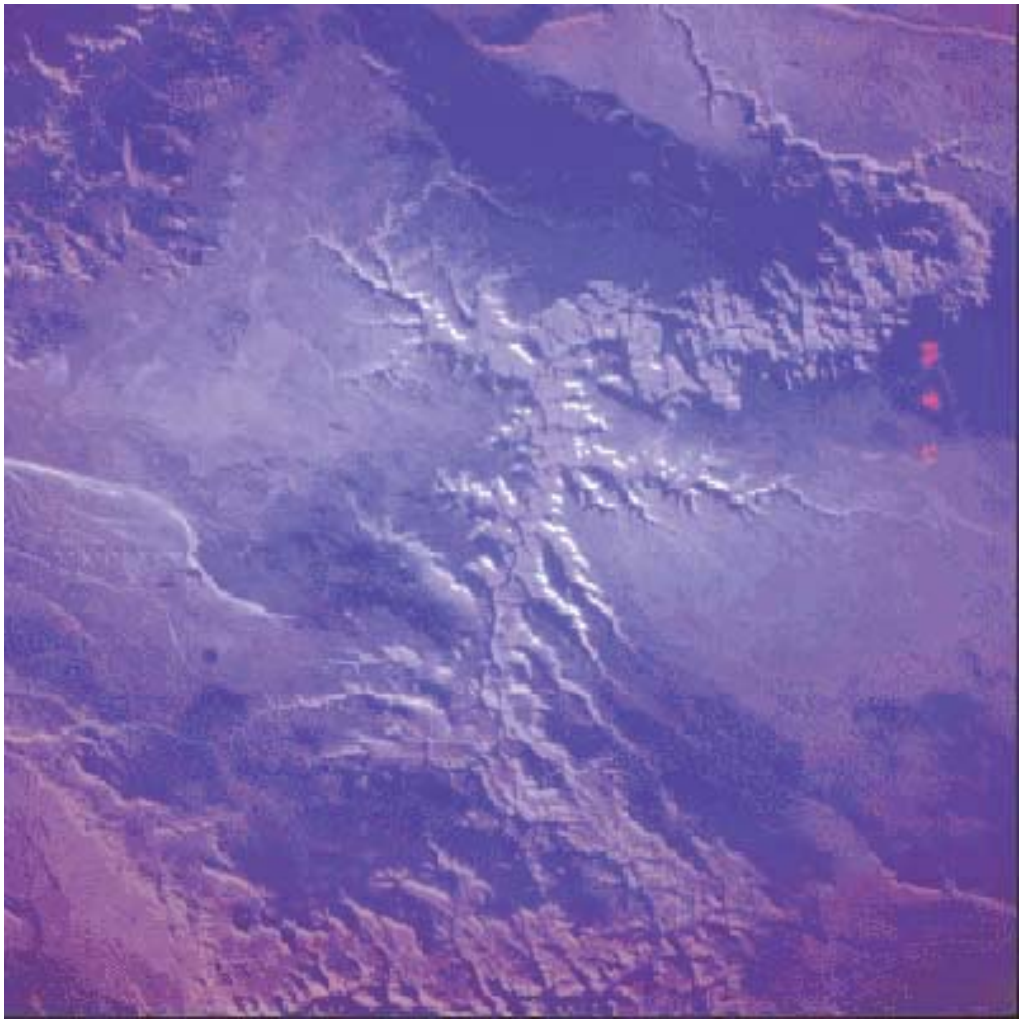
Inner Planets: Surface of Venus



http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-venus.html

Inner Planets: Earth as a Planet

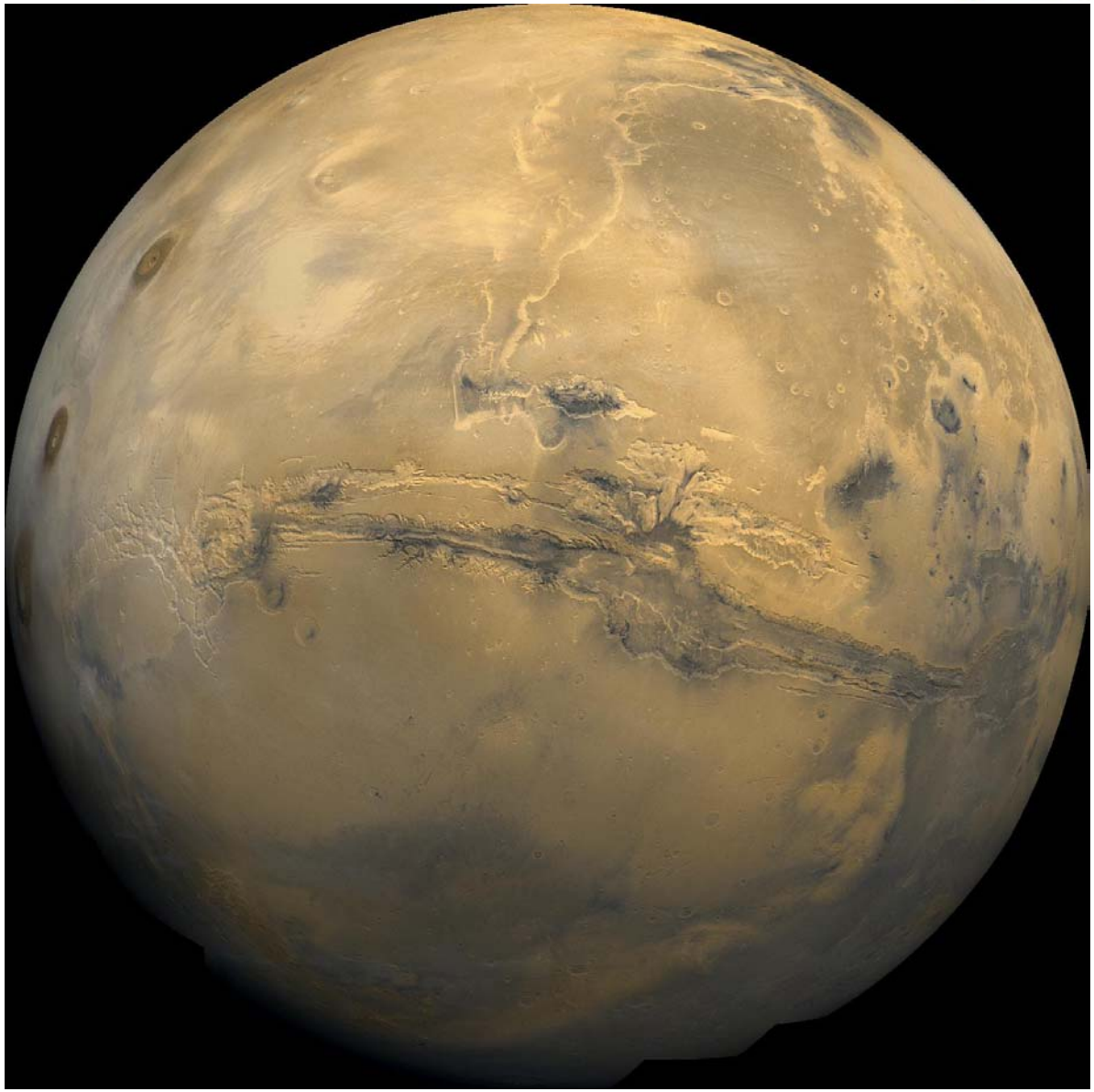




http://pds.jpl.nasa.gov/planets/choices/earth1.htm

Inner Planets: Mars

- 1.52 AU from Sun
- Only planet whose surface features can be seen from Earth-based telescopes.
- Some surface features seen from spacecraft suggest that there was once flowing water on Mars.

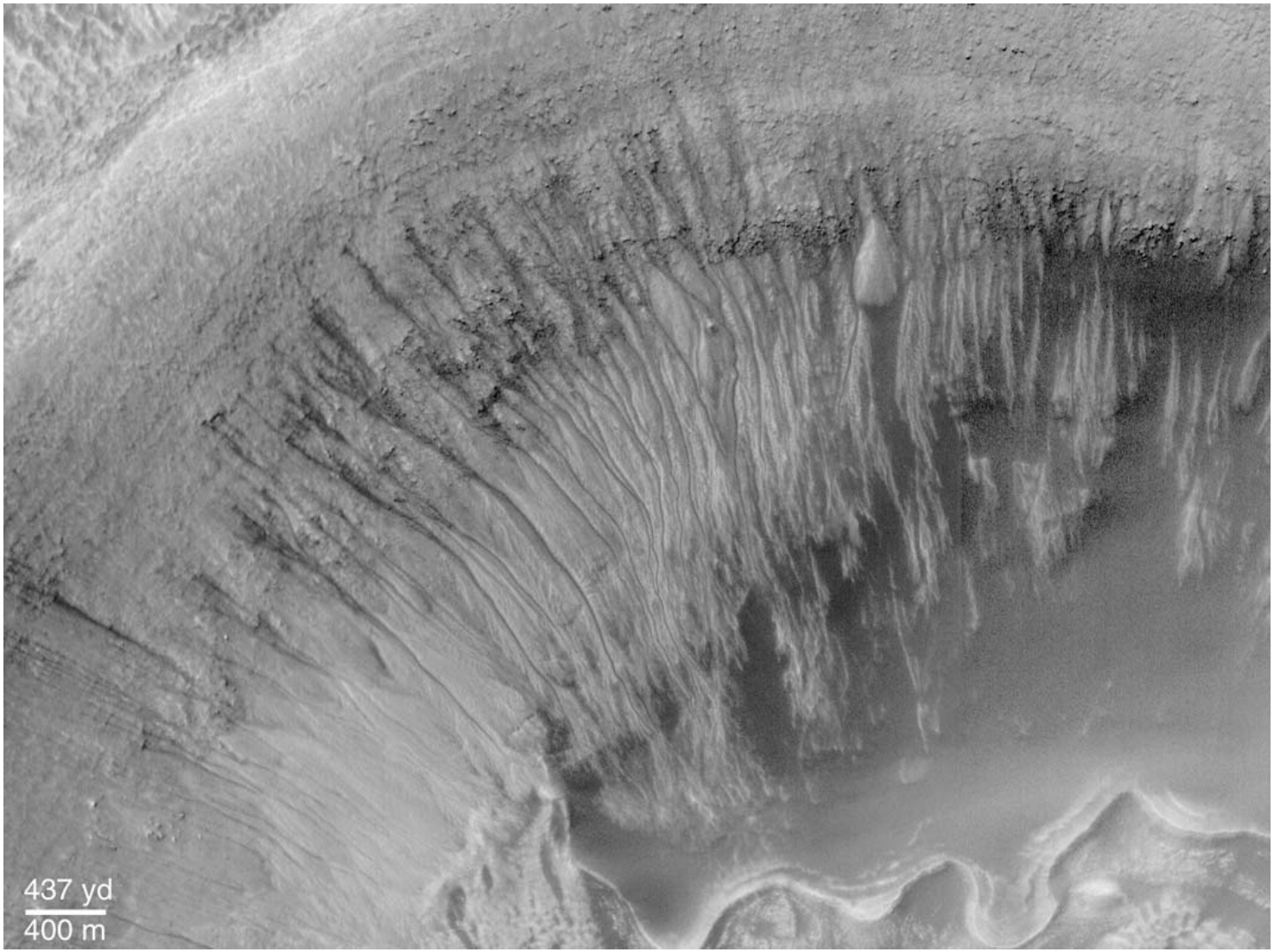


http://www.seds.org/nineplanets/nineplanets/mars.html

Mars: Surface

http://www.grc.nasa.gov/WWW/PAO/html/marspath.htm

Mars: Surface– Evidence for Water



http://antwrp.gsfc.nasa.gov/apod/image/0006/marsnewton_mgs_big.jpg

Mars: Olympus Mons

- The largest mountain in the Solar System rising 24 km (78,000 ft.).

- Its base is more than 500 km in diameter and is rimmed by a cliff 6 km (20,000 ft) high (right).

http://hyperphysics.phy-astr.gsu.edu/hbase/solar/marsoly.html

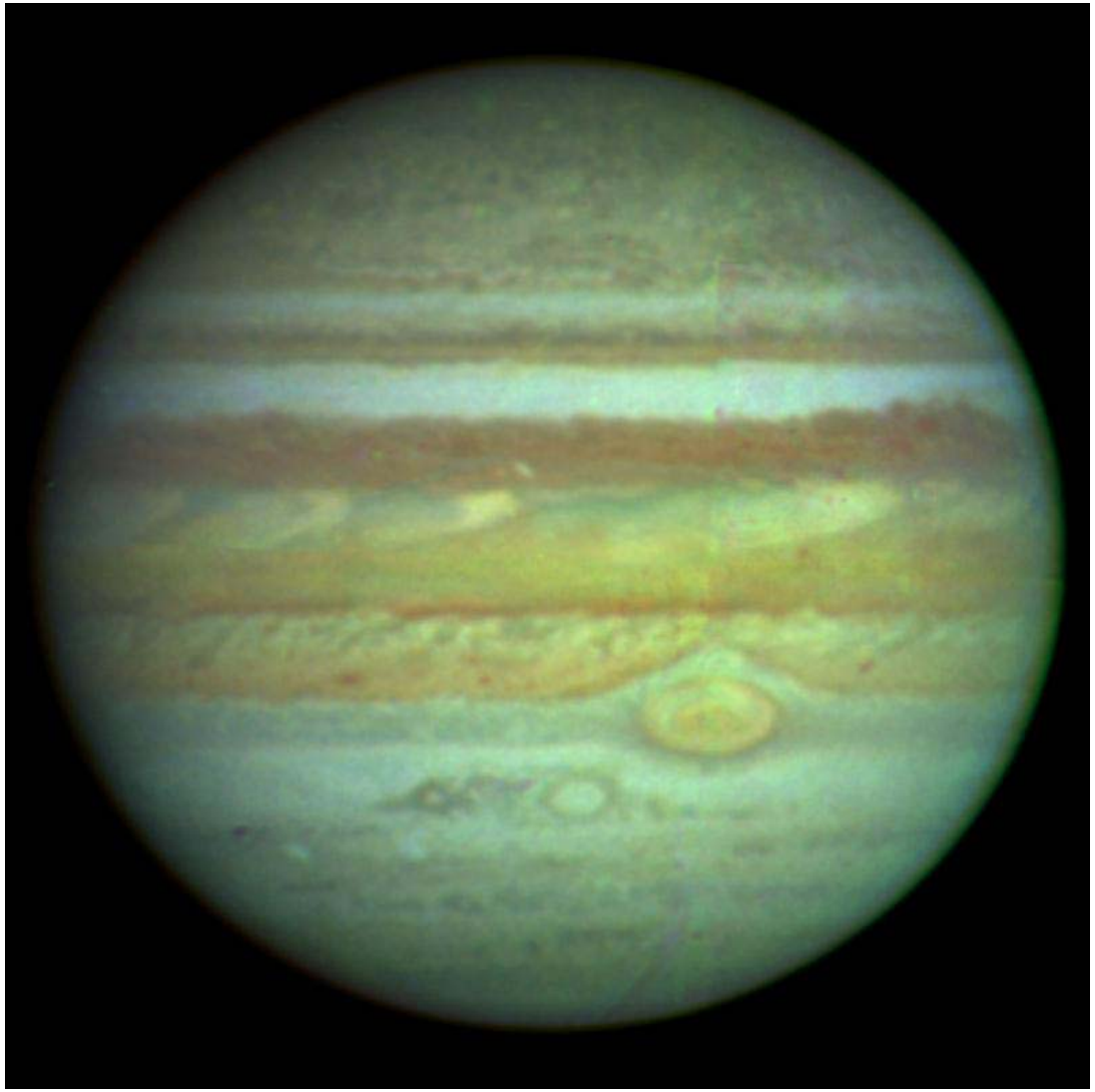
Junk? Asteroids-- Eros

- Between Mars and Jupiter, there are millions of asteroids ranging in size from dust to 900 km in size.
- Eros is actually labeled a near-Earth asteroid, as its orbit brings it close to Earth. 33 x 13 x 13 km in size.
- Semimajor Axis: 1.458 AU

http://near.jhuapl.edu/iod/20000222/index.html

Jupiter– Big Boy

- 5.2 AU from Sun
- By far the largest and most massive planet.
- No solid surface. The gas just gets denser as we get deeper.
- 90% Hydrogen and 10% Helium with traces– like the early solar system.
- Has 61 known moons.



http://www.ast.cam.ac.uk/hubblepics/

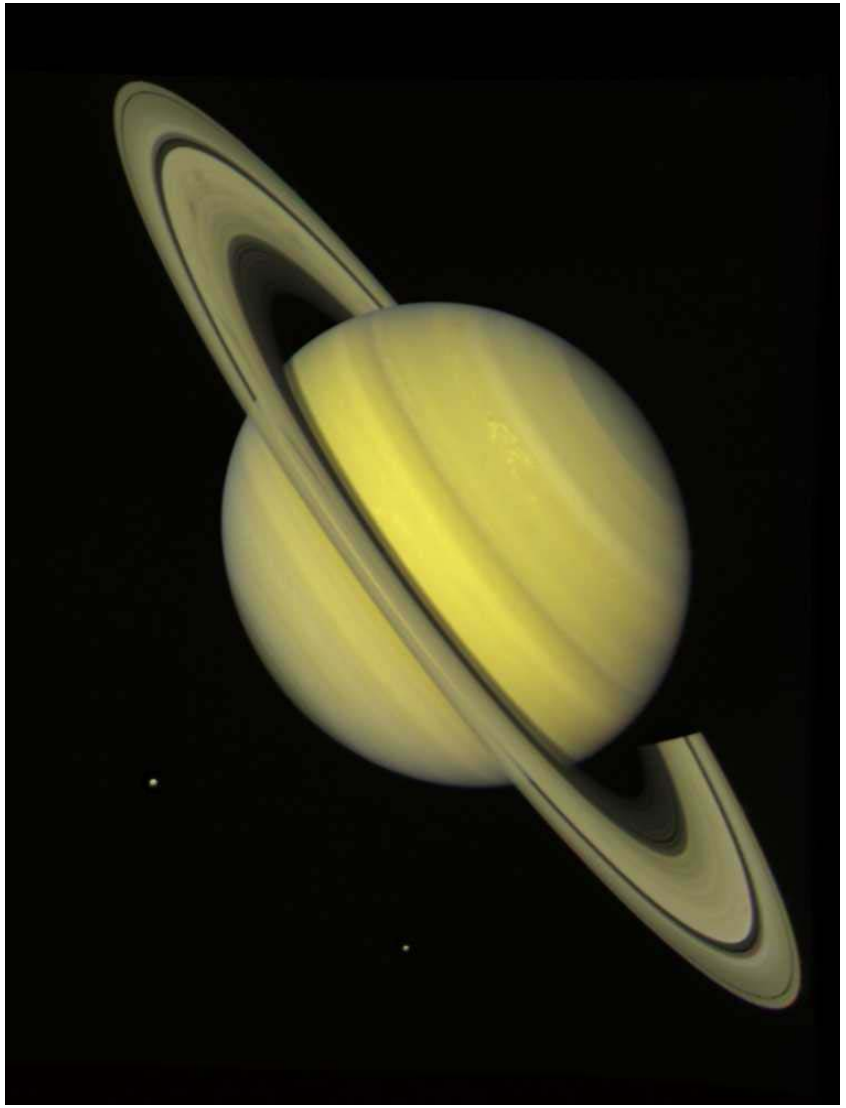
Jupiter

http://www.solarviews.com/raw/jup/vjupitr5.mpg

http://www.solarviews.com/raw/jup/vjupitr2.mov

Outer Planets: Saturn

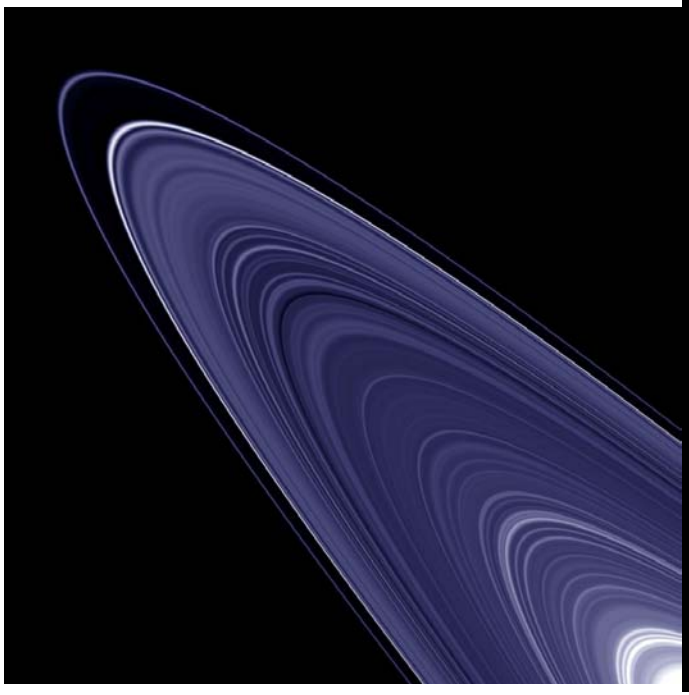
- 9.54 AU from Sun
- The Lord of the Rings
- Ring has gaps
- Only planet less dense than water
- Broad atmosphere banding is similar to Jupiter
- http://www.solarviews.com/raw/sat/vsaturn1.mpg
- http://www.solarviews.com/raw/sat/spoke.mov

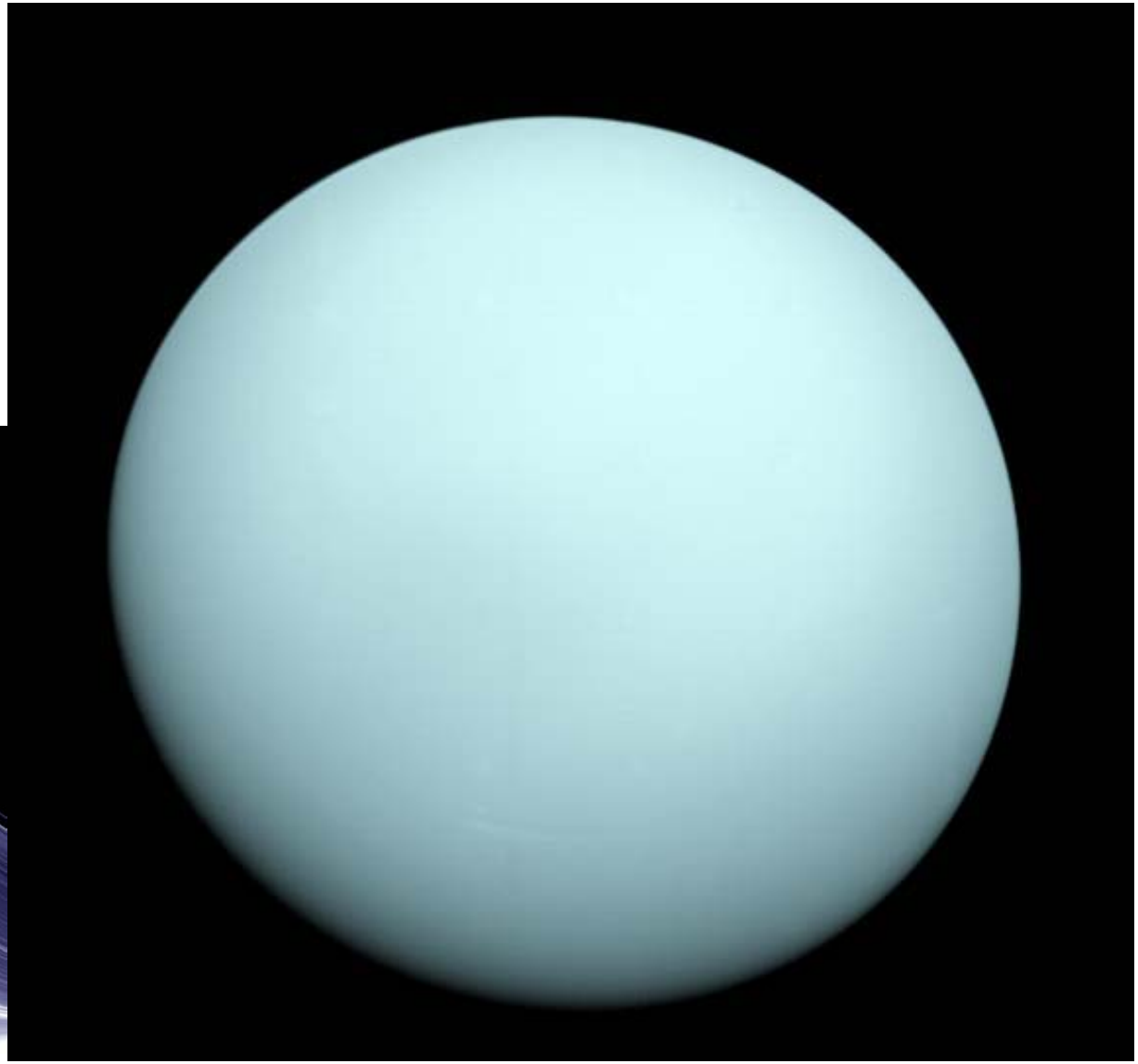


http://www.solarviews.com/cap/sat/saturn.htm

Outer Planets: Uranus

- 19.2 AU from Sun
- In 1977 the rings of Uranus were discovered.
- Tilted axis of rotation (98 degrees)

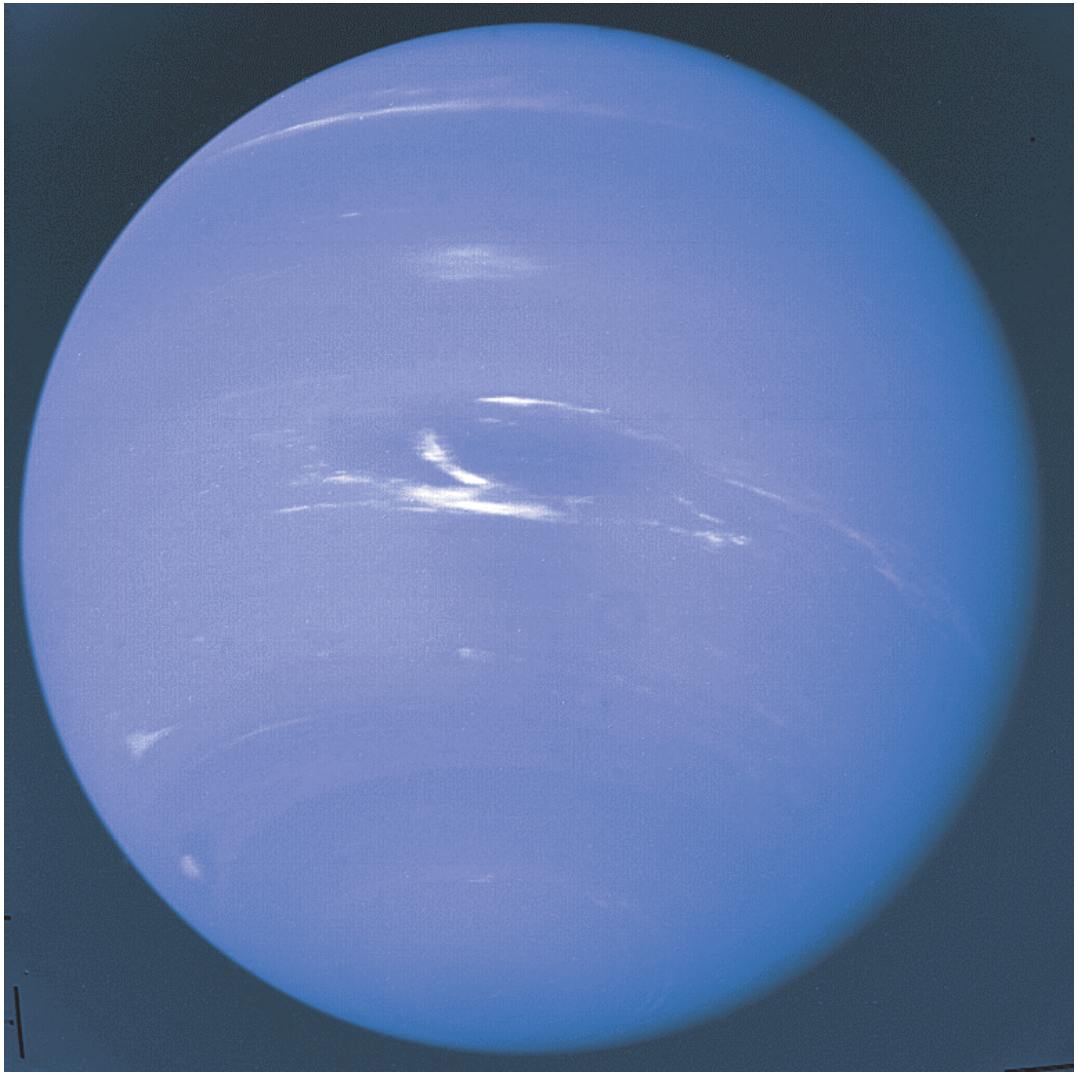




http://www.solarviews.com/eng/uranus.htm

Outer Planets: Neptune

- 30.06 AU from Sun
- Outermost Gas Giant
- Methane gives it the blue color
- Has the fastest record wind speed of 2000 km/hr.
- Also has a faint ring system
- Seasons last 40 years!



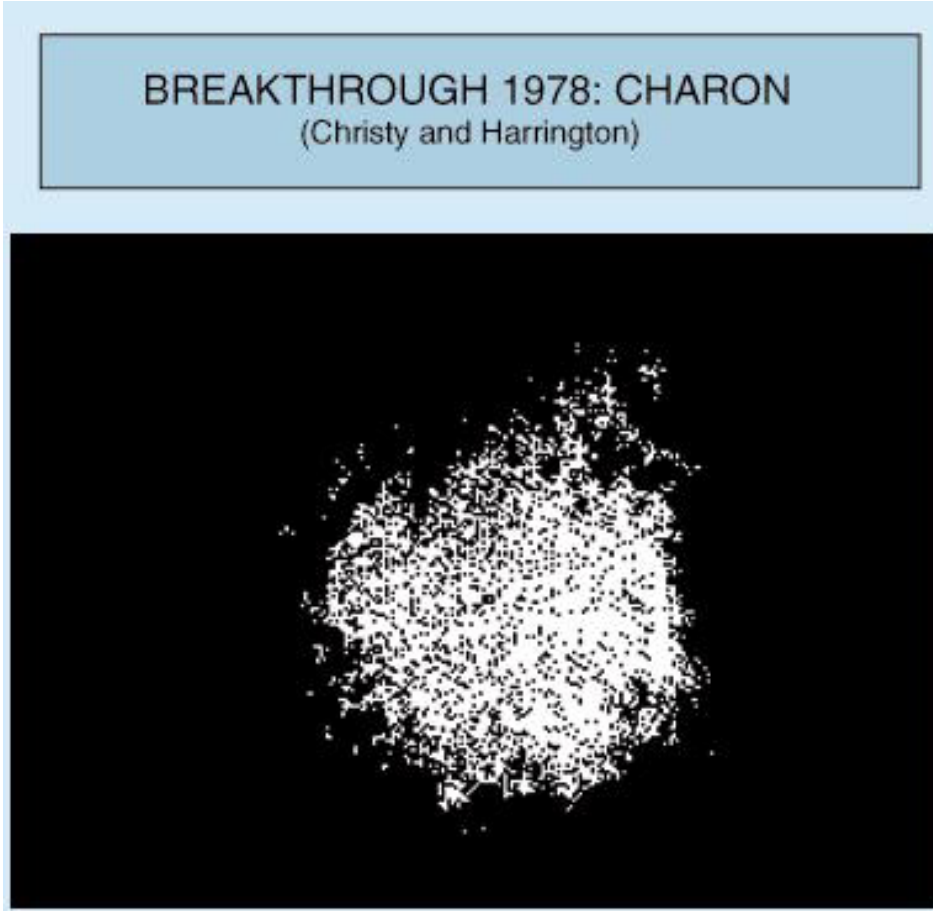
http://www.solarviews.com/cap/nep/neptunes.htm

Outer Planets: Neptune

http://www.solarviews.com/raw/nep/vneptune.mov

Pluto

- 39.53 AU from Sun
- Discovered in 1930 by telescope in AZ.
- A blob was noticed in 1978 that circled Pluto every 6 days. It proved that Pluto had a moon. Later named Charon.



http://www.solarviews.com/cap/pluto/hstpluto.htm

Pluto

- The only planet not yet visited by a spacecraft
- Has tilted and very eccentric orbit
- Moon Charon and Pluto always face each other

- Gravity pull is only 8% of Earth's.
- Smallest Planet? Or not?

http://www.solarviews.com/cap/pluto/hstpluto.htm

Pluto

http://www.solarviews.com/raw/pluto/vpluchar.mpg

The Structure of the Solar System

- What are the furthermost solar system objects from the sun?
  - icy objects/comets

Furthermost objects form the Oort cloud

Outer: Comets

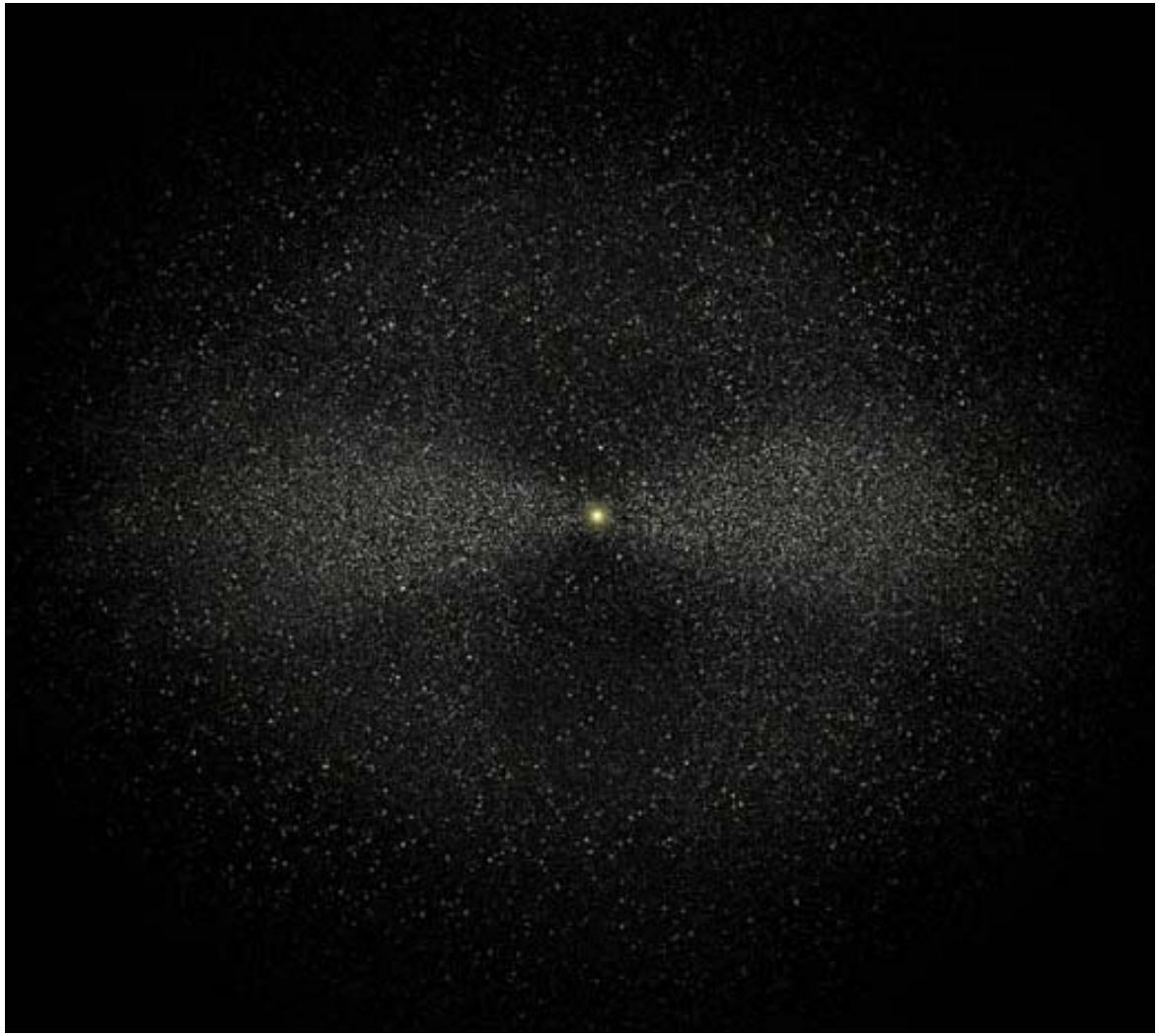
- Beyond orbit of Pluto, there are hundreds of billions of comets. Many of these are in a flat disk-like structure called the Kuiper belt. But more are in a spherical cloud further out called the Oort cloud.

Space Junk? Comets

http://www.jpl.nasa.gov/comet/gif/pach15.jpg

Oort Cloud

- Most comets located in the outer solar system
- Source of long term comets
- 100000 AU outward
- Edge of Sun's gravitational influence
- Spherical distribution, not only in ecliptic



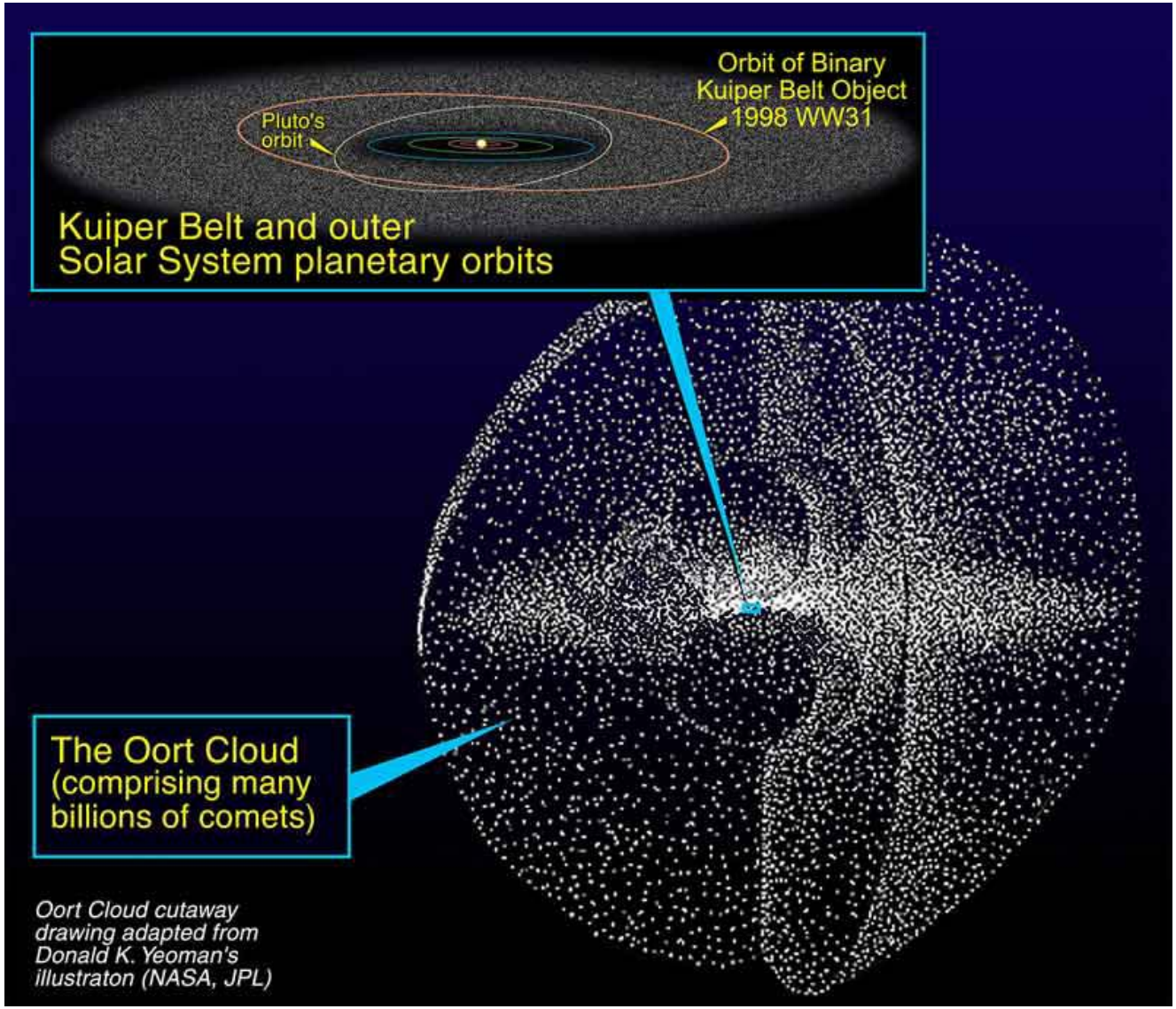
http://www.etsimo.uniovi.es/solar/cap/comet/oort.htm

Example

Passing star perturbs Oort cloud

Kuiper Belt

- **Source of short term comets**
- **Doughnut-like in ecliptic plane**
- **30-100 AU**
- **Can detect these objects!**

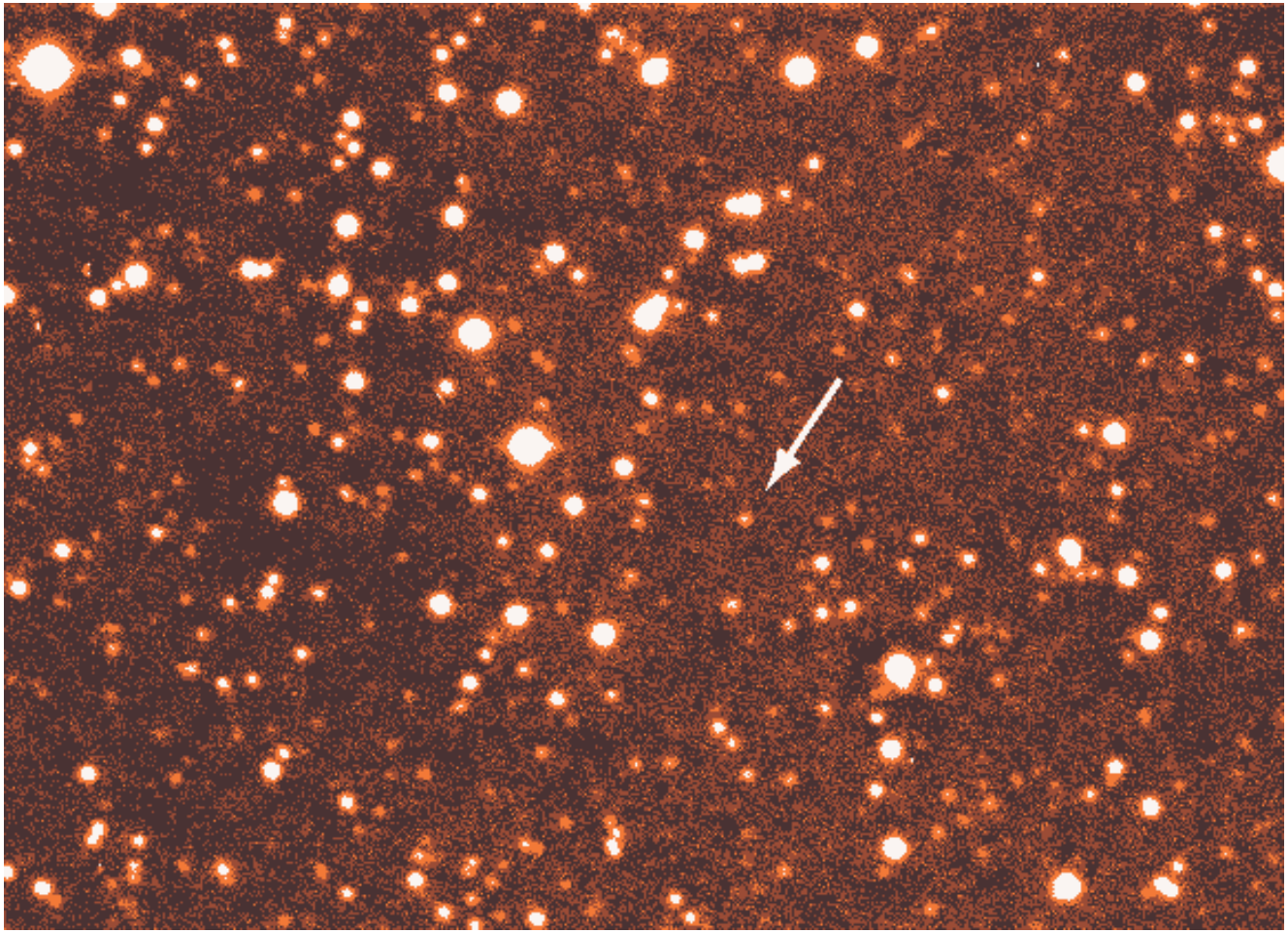


Do we know of all of the Bodies in our Solar System?

- No. Even at this age, we are still discovering new comets, or large asteroids, or even?

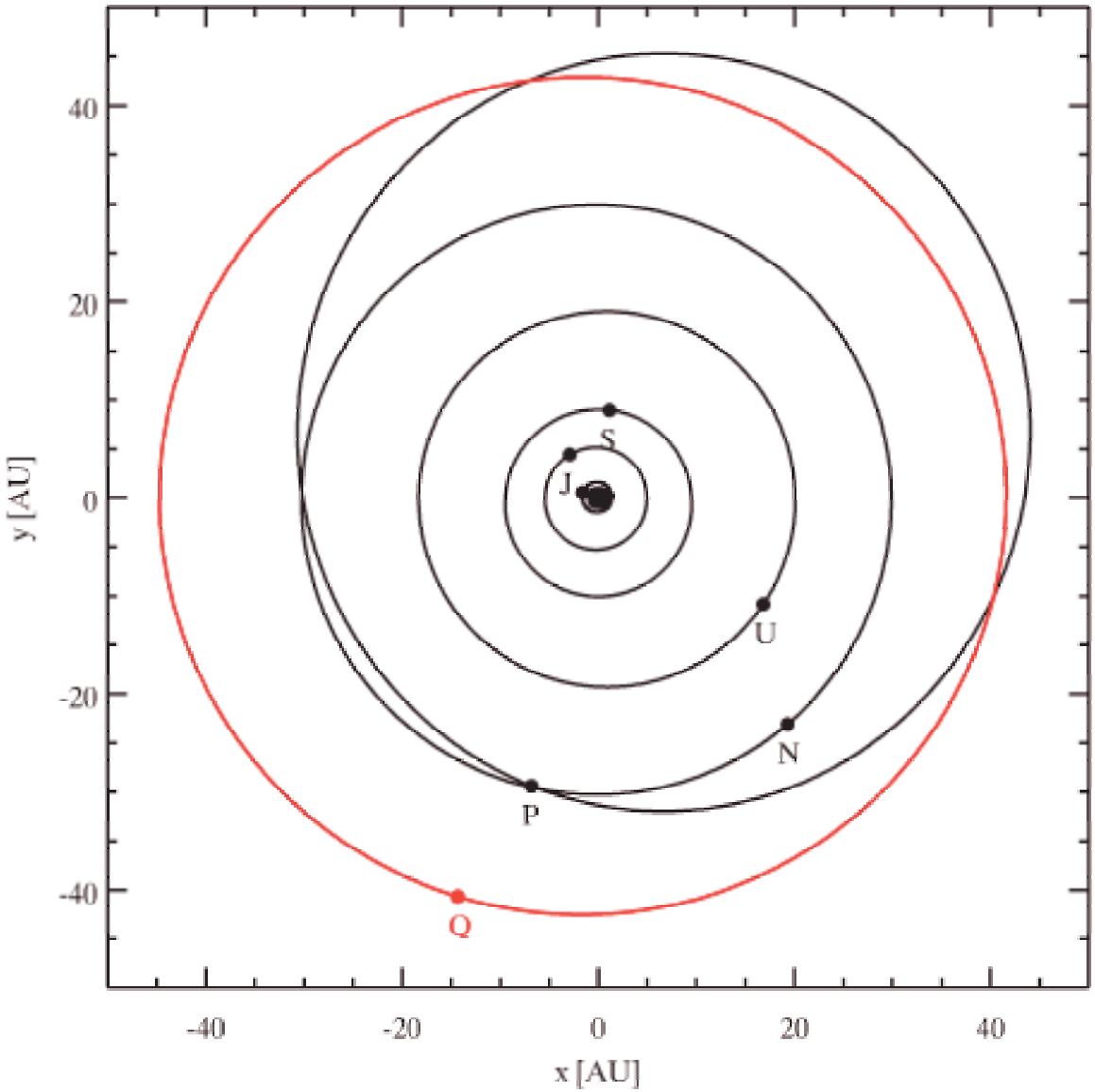
New Data-- Kuiper Object Quaoar : Found 2002

- Most recent and BIGGEST discovered yet
- pronounced kwa-whar
- diameter of about 800 miles (half of Pluto)
- 42 AU orbit



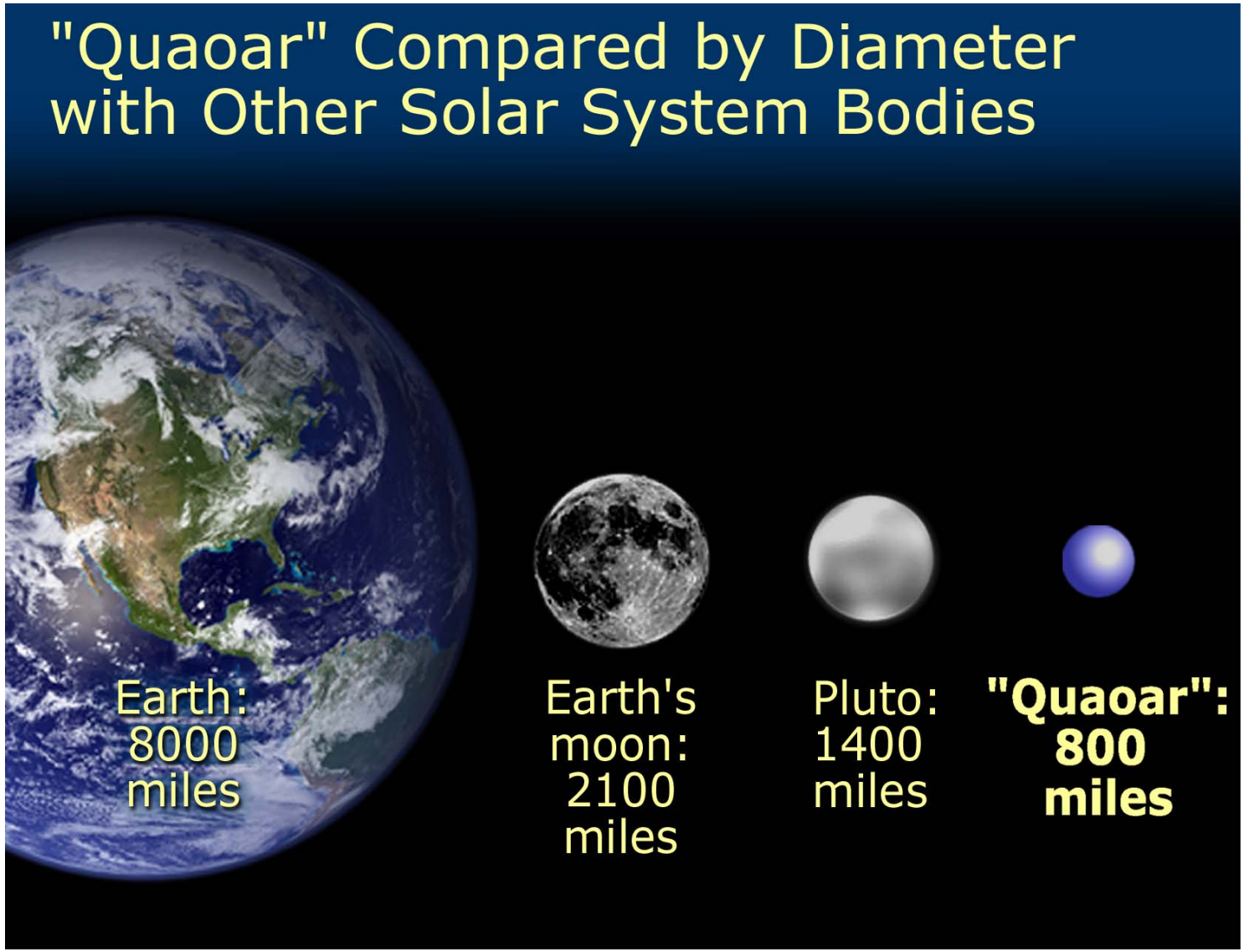
http://antwrp.gsfc.nasa.gov/apod/ap021009.html

Quaoar Orbit



http://www.gps.caltech.edu/~chad/quaoar/

Quaoar Comparison

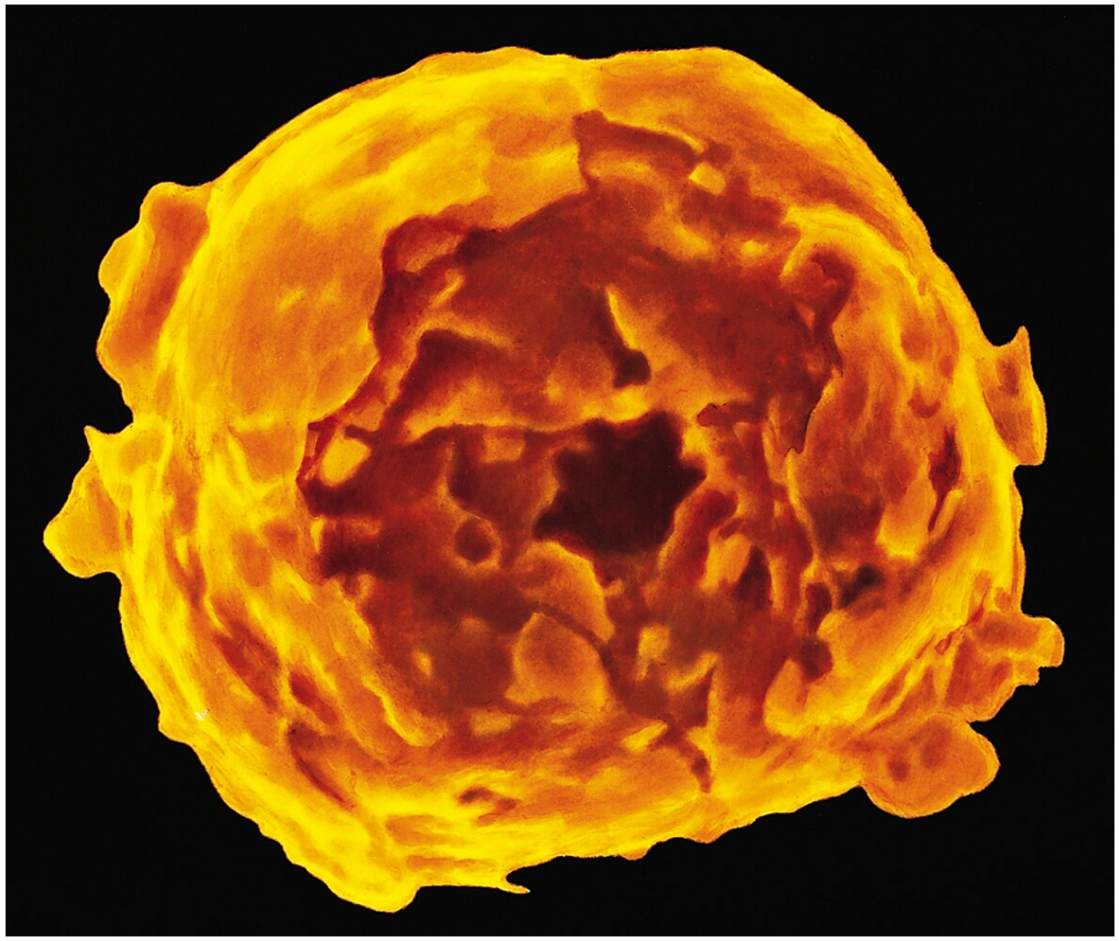


Or Huya (Venezuelan Rain God)

- Discovered in March 2000, but only recently named.
- About 600 km in diameter (1/4 that of Pluto)
- 256 years to orbit
- Reddish in color
- Semi-major axis of 39 AU

Lots of Dust

- Interplanetary Dust is abundant and similar in composition to what we see outside of our solar system.
- About 2-20 microns in size– a human hair is 100 microns in diameter



Planet Comparisons

TABLE II-1 Orbital Characteristics of the Planets

	Average distance from Sun (AU)	Average distance from Sun (10^6 km)	Orbital period (yr)
Mercury	0.39	58	0.24
Venus	0.72	108	0.62
Earth	1.00	150	1.00
Mars	1.52	228	1.88
Jupiter	5.20	778	11.86
Saturn	9.54	1427	29.46
Uranus	19.19	2871	84.01
Neptune	30.06	4497	164.79
Pluto	39.53	5914	248.54

Planet Comparisons

TABLE II-2 Physical Characteristics of the Planets

	Diameter		Mass		Average density
	(km)	(Earth = 1)	(kg)	(Earth = 1)	(kg/m^3)
Mercury	4,878	0.38	3.3×10^{23}	0.06	5430
Venus	12,100	0.95	4.9×10^{24}	0.81	5250
Earth	12,756	1.00	6.0×10^{24}	1.00	5520
Mars	6,786	0.53	6.4×10^{23}	0.11	3950
Jupiter	142,984	11.21	1.9×10^{27}	317.94	1330
Saturn	120,536	9.45	5.7×10^{26}	95.18	690
Uranus	51,118	4.01	8.7×10^{25}	14.53	1290
Neptune	49,528	3.88	1.0×10^{26}	17.14	1640
Pluto	2,300	0.18	1.3×10^{22}	0.002	2030

Planet Comparisons

- Mercury, Venus, Earth, and Mars are crowded close to the Sun.
- The four large planets– Jupiter, Saturn, Uranus, and Neptune– are widely spaced
- Pluto tends to be in unusual space
- Mostly circular orbits, except Mercury and Pluto
- Orbits all lie in a plane
- Size varies considerably– smallest giant is 4 times larger than Earth, the largest inner planet
- Pluto is smaller than the 7 largest moons
- Gas giants are all massive

Planet Comparisons

- 4 inner planets have higher average densities
- Gas giants have low density– made from light elements
- Pluto is an oddity– rock and ice
- 3 groups of planets– inner (terrestrial), the gas giants (Jovian), and Pluto
- Only Mercury and Venus do not have moons

Terrestrial vs. Jovian Planets

Terrestrial Planets	**Jovian Planets**
Small size, low mass	Large and massive
Dense, rocky solid surfaces	Low density, huge gaseous atmospheres
Close to the Sun (within 1.5 AU)	Farther away (from 5.2 to 30 AU)
Heavy gas atmospheres (N_2, O_2, CO_2)	Lighter elements, H and He
Slow rotators	Faster rotators, differential rotation
Few satellites (3)	Many moons (over 60)
Weak magnetic fields	Strong magnetic fields
No ring system	Planetary rings

What is Stuff?

- One of the biggest questions has been: What is stuff made out of?

- We know that things can be broken into small bits that defines the stuff– Atoms.

Atoms In Perspective

- Imagine yourself on a beach. You see the smallest grain of sand that you can find– stuck between your toes. How many atoms does it have? More than…

1. All the people in this room?
2. All the people in the Memorial Stadium during a Football game.
3. The population of Chicago.
4. The population of the World.